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COMMENTS ON ASME PAPER NO. 64-HT-12

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It is interesting to note the apparent contradiction between the abstracts of this paper and reference (A-1) concerning the significance of the temperature dependence of thermal and transport properties on Nusselt type correlations. Reference (A-1) reexamined the data of six very extensive heated tube investigations which were conducted over a wide range of conditions. The most significant of these conditions were bulk temperature, which ranged from 200 to 3000°R, and the wall to bulk temperature ratio, which was as high as 10. The primary conclusion, from this analysis was that data obtained by measurements of q'', w, T_w, $T_{b,in}$ and D can be correlated independent of thermal and transport property variations which is apparently a contradiction to the abstract of this paper. In this paper the authors present the results of a carefully conducted experiment and provide an independent set of local heat transfer data which can be examined in an effort to resolve this apparent contradiction between the two papers. We wish to thank the authors for making reference (A-2), which contains a portion of the data used in their paper, available to us for this discussion.

The seat of this contradiction seems to lie in the approach to the problem. Most recent investigators, the authors included, have felt that the variations within the system must have a significant influence on the heat transfer process. With this we are in full agreement, and it is the concept which forms a common basis for approach to the problem.

The first approach is the conventional one taken by the authors. That is to attempt to account for property variations and to demonstrate their significance by specifying that properties in the Dittus-Boelter equation be evaluated

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as a function of some local reference temperature (such as local bulk temperature). This temperature dependent Nusselt equation is then cross plotted against other system parameters to determine their influence as was done in fig. (2). The final result is an accurate correlation of the data such as presented by the authors in fig. (3) and equation (6).

A second, parallel, approach is to eliminate the properties and attempt to illustrate their significance by investigating the effects of the other system parameters, q'', w, Tw, Tb_{in} and D, on the heat transfer process. Fig. (A-1) is a result of this type of examination of the data selected for analysis in reference A-1. This figure is the same as figure (3) of reference (A-1) but has been updated to include more local stations from the data referenced therein. This figure indicates that turbulent heat transfer data can be correlated utilizing only system parameters independent of property variations by the following equation:

$$h = KG^{.8}d^{-.2}\sqrt{Tb/Tw} \qquad \text{(A-1)}$$

where K is a dimensional constant unique to each gas and can be calculated by a procedure outlined in reference (A-1).

This same approach is applied to the data of reference (A-2) in fig. A-2, and it also seems to correlate independent of properties. The limited helium data compares well with fig. (A-1); however, the air data falls lower than the corresponding intercept value. This probably is due to a difference in experiments. Using the calculation procedure mentioned above, a value of K = 0.00382 $Btu/^{o}R\ lb_m^{.8}h_r^{.2}ft^{.2}$ was predicted for air in Table 3, reference (A-1), and this value agrees very favorably with K = 0.00380 of fig. A-2. There is also considerable scatter in this figure for data taken at $x/D < 3$. The x/D modification of equation (6) is introduced into the data in fig. A-3. The results seem to

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emphatically reinforce the conclusion that data based on measurements of q", w, Tw, Tb in and D can be correlated independent of thermal and transport property variations.

To demonstrate that these approaches are parallel but attain different results equation (6) is regrouped:

$$h = .021\ (K^{.6} C_p^{.4}/\mu^{.4})\ G^{.8} d^{-.2}\ (Tw/Tb)^{-.5}\ \left[1 + (x/D)^{-.7}\right] \text{ - - - (A-2)}$$

The similarity between equation (A-2) and the parametric grouping of fig. (A-3) is really apparent:

$$h = K\ G^{.8} d^{-.2} \sqrt{Tb/Tw}\ \left[1 + (x/D)^{-.7}\right] \text{ - - - - - - - - - - - - - - - (A-3)}$$

Thus examination of the same equation from two different points of view has yielded seemingly contradictory results.

It appears that these conflicting results, while startling and possibly useful from a design point of view, indicate that neither of these approaches answers the important question of the significance of property variations on heat transfer. Neglecting properties in equation (A-1) does not say they are NOT important any more than including them in equation (A-2) demonstrates their significance. All that can be concluded from these figures is that the heat transfer system responds to changes in properties such that the system parameters q", w, Tw, Tb in and D reflect this response in a unique functional manner. Thus the common premise that thermal and transport property variations should be important remains unchanged and further work is necessary in the area.

The contradiction in the role of transport properties remains unresolved; however, its existence indicates that measurements of q", w, Tw, Tb in and D while they are necessary are not sufficient to determine the relationship of properties to turbulent heat transfer to a gas.

A-1 Simoneau, R. J., and Hendricks, R. C., "A Simple Equation for Correlating Turbulent Heat Transfer to a Gas," ASME Paper No. 64-HT-36.

A-2 McEligot, D. C., "Effect of Large Temperature Gradients on Turbulent Flow of Gases in the Downstream Region of Tubes," TR-247-5, Stanford University, March 1963, Stanford California.

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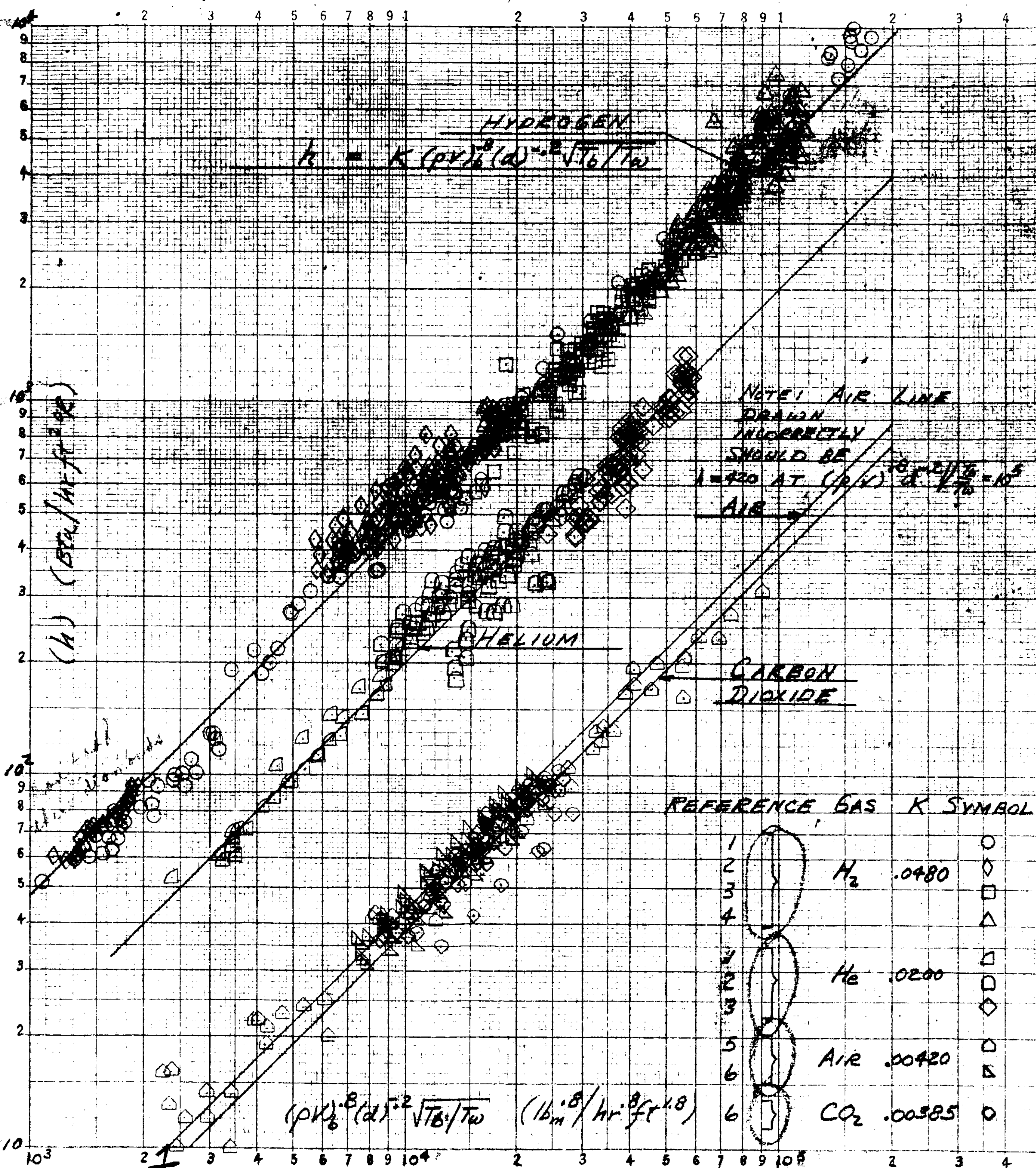

FIGURE 1. (A-1) EFFECT OF MASS VELOCITY, $(\rho V)_b$, TUBE GEOMETRY, (d), AND WALL TO BULK TEMPERATURE RATIO, (T_w/T_b), ON HEAT TRANSFER COEFFICIENT, (h).

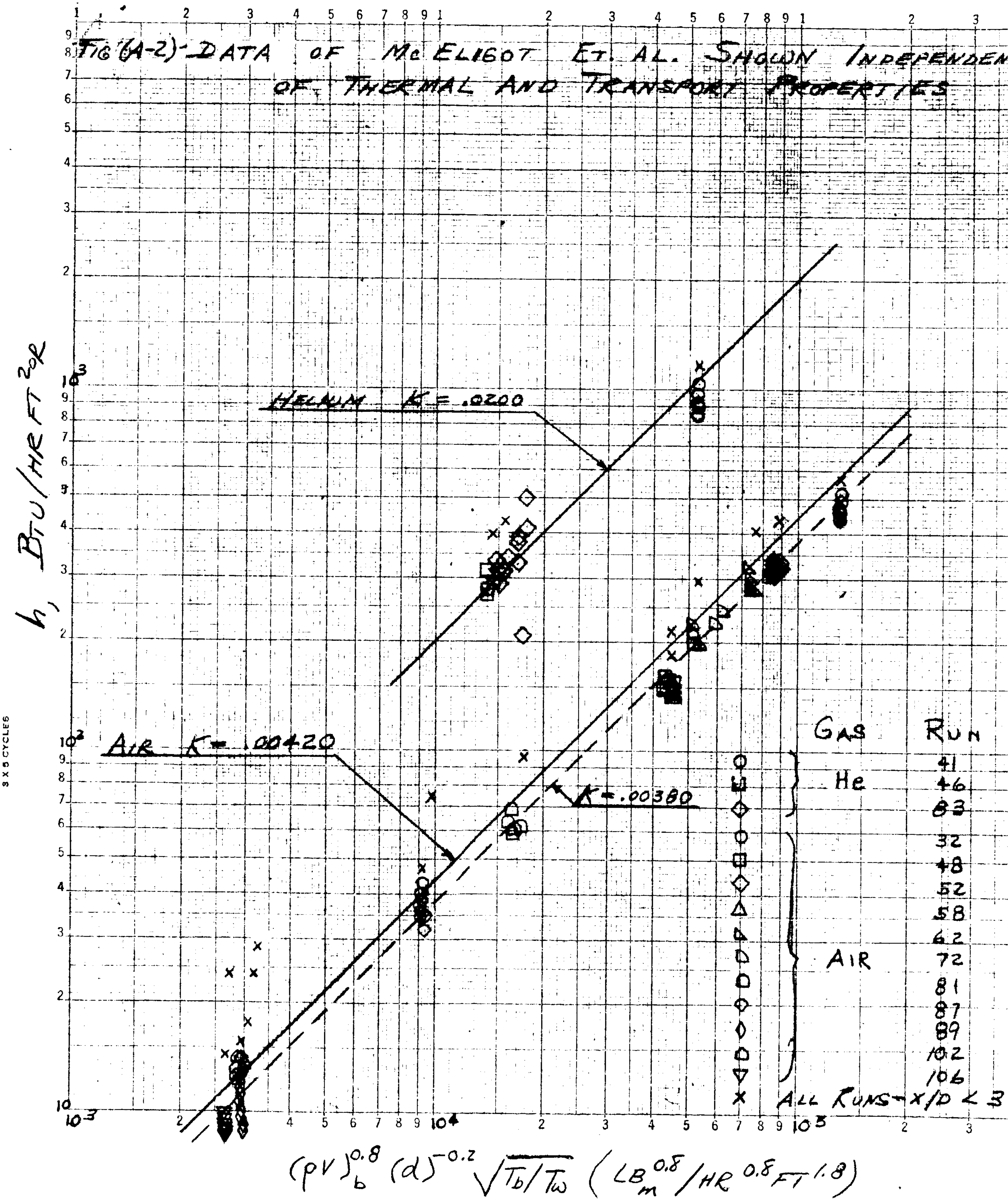

FIG (A-2) - DATA OF McELIGOT ET. AL. SHOWN INDEPENDEN[T] OF THERMAL AND TRANSPORT PROPERTIES

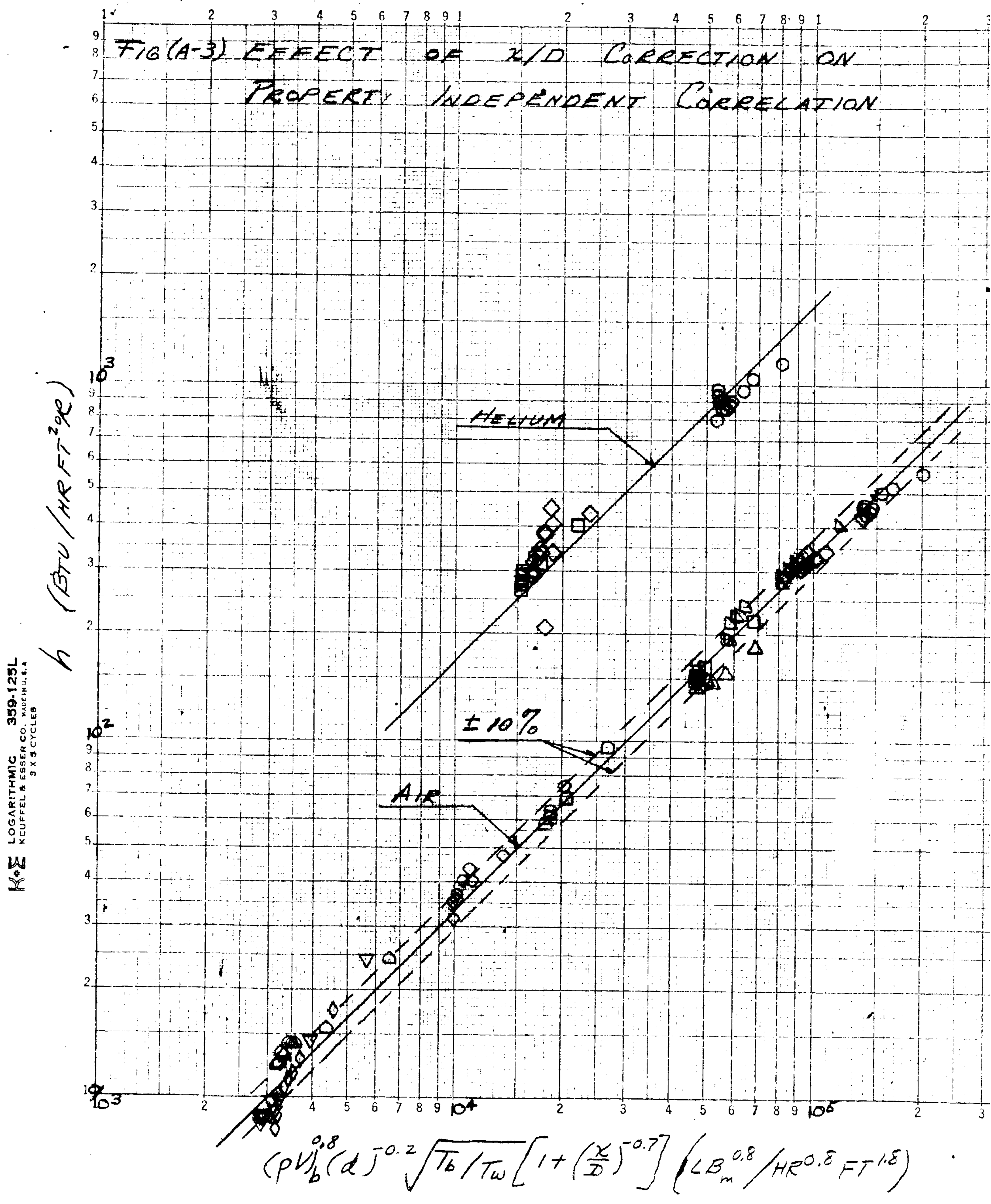

FIG (A-3) EFFECT OF X/D CORRECTION ON PROPERTY INDEPENDENT CORRELATION